C. B. Schmeltzer

Floods in Kaskaskia River, Illinois and Probable Effect of Straightening the Channel

FLOODS IN KASKASKIA RIVER, ILLINOIS AND PROBABLE EFFECT OF STRAIGHTENING THE CHANNEL

BY

CHAUNCEY BROCKWAY SCHMELTZER

B. S. University of Illinois, 1919

THESIS

Submitted in Partial Fulfillment of the Requirements for the

Degree of

MASTER OF SCIENCE

IN CIVIL ENGINEERING

IN

THE GRADUATE SCHOOL

OF THE

UNIVERSITY OF ILLINOIS

1920

UNIVERSITY OF ILLINOIS

THE GRADUATE SCHOOL

______________191__

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY Chauncey Brockway Schmeltzer

ENTITLED Floods in Kaskaskia River, Illinois and Probable Effect of Straightening the Channel

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF Master of Science

G. W. Pickels
In Charge of Thesis

F. H. Newell
Head of Department

Recommendation concurred in*

______________ Committee
______________ on
______________ Final Examination*

*Required for doctor's degree but not for master's

FLOODS IN THE KASKASKIA RIVER, ILLINOIS

AND PROBABLE EFFECT OF STRAIGHTENING THE CHANNEL

CONTENTS

I. Introduction

II. The Situation

III. Precipitation

IV. Stream-flow and Run-off

V. Determination of n

VI. The Effect of Straightening

VII. Conclusion

PLATES

1. State of Illinois showing Kaskaskia Watershed.

2. Kaskaskia Watershed.

3. Extent of Bottomlands

4. Table of Annual Precipitation

5. Diagram of Mean Annual Precipitation

6. Table of Monthly Precipitation

7. Rating Curve for Vandalia

8. Rating Curve for Carlyle

9. River stage Hydrographs of the Kaskaskia River

10. Table of Days per Month of Overflow

11. Data for River Stage Duration Curve at Vandalia

12. Data for River Stage Duration Curve at Carlyle

13. Duration Curves

14. Precipitation over the Kaskaskia Watershed during the Flood in May 1908

15. Discharge at Carlyle during the May 1908 Flood

16. Diagram of Precipitation and Discharge at Carlyle during the Flood in May 1908

17. Determination of n

18. Proposed Straightening, Carlyle to Vandalia

19. Proposed Straightening, Vandalia to Cowden Bridge

20. Length of Proposed Channel, Carlyle to Vandalia

21. Length of Proposed Channel, Vandalia to Cowden Bridge

22. Effect of Straightening on the Storage of Flood Waters between Cowden Bridge and Vandalia

23. Effect of Straightening on the Storage of Flood Waters between Vandalia ad Carlyle

I. INTRODUCTION.

This thesis is a discussion of the proposed straightening of the portion of the Kaskaskia River from Cowden Bridge in the south side of Shelby County to Carlyle, the county seat of Clinton County. Precipitation and run-off data will be presented as they apply to the problem under consideration. The straightening of the river will increase the discharge thru that portion. This will tend to prevent flooding in the area improved, but will have an opposite effect on the area below the improvements.

A peculiar feature of interest in this problem is the effect of improving only a portion of the stream. In a well-drained river-basin the main stream and its tributaries are naturally adjusted to each other with respect to width, depth and slope. The head waters as they flow down the valley from the net work of upland streams are properly accommodated at the junction points by channels adequate to carry their combined volumes. The channel increases in cross-section with each added increment of flow. If this increase in the main channel does not exist, the waters as they come from the tributary streams will spread out over the lower areas and a swamp will be formed. This is the condition which drainage attempts to relieve, yet in many instances it is the condition that drainage creates or increases.

Every proposed drainage project must consider the entire water-shed. It is not sufficient to dig ditches thru a large area and discharge the water into streams that are not adapted to the increased rate of flow, but rather these natural streams must be enlarged and improved as far down their courses as is necessary to provide adequately for the increased flow. To do this it will be necessary to extend the channel enlargements far beyond the area immediately improved. The new channel will be of benefit out-

side of the actual boundaries of the district. This should be paid for by those who though outside the district, yet receive the benefits. The drainage of a swamp should logically and financially comprise all the lands in the particular basin. There must be participation in the expense by every land owner receiving benefit, if there is to be an equitable distribution of expense.

In this problem, a portion of the Kaskaskia River in the upper portion of the overflowed area is to be straightened and improved. The flooding of the area immediately below is now even worse than that in the area under consideration. Thru the upper section the flow will be increased and the time of concentration so shortened that the stream below will receive more water than before and will be taxed far beyond its capacity. How much the flow will be increased and what effect this increased flow will have on the lower and unimproved stretches of the river will be presented in the following pages.

The data used in this thesis are taken from the "Report and Plans for the Reclamation of Lands Subject to Overflow in the Kaskaskia River Valley in Illinois" prepared by Jacob A. Harman. This investigation was at first under the direction of the Internal Improvement Commission of the State of Illinois, and was finally completed in 1911 under the Rivers and Lakes Commission of Illinois. The plan of the latter body dealt with the reclamation of the entire river. At present the work proposed and being surveyed includes only the portion of the river from Cowden Bridge just above the Fayette-Shelby County line to Carlyle in Clinton County.

The precipitation records were gathered from Bulletin No. 208, "Climate of Illinois", published by the Agricultural Experiment Station of the University of Illinois. This bulletin is a summary of the climatological

data for the State of Illinois and contains all available precipitation records for the various stations over the state. Daily precipitation records were taken from the Report of the Illinois Section of the Climatological Service of the Weather Bureau. River-stage and-flow records were taken from Water Supply Papers Numbers 245, 265, 285, 305, 325, published by the U. S. Geological Survey.

II. THE SITUATION.

The Kaskaskia River Valley is in the southewestern part of the State of Illinois. The stream rises in the central part of Champaign County and flows southwesterly to the Mississippi River just above Chester in Randolph County. Plate I shows the location of the Kaskaskia Watershed with reference to the other streams and the remainder of the state. The course on the stream is shown in greater detail on Plate 2, together with the stations at which the precipitation and run-off were measured. On Plate 3 is shown the extent of the bottom lands along the Kaskaskia River from Carlyle to Cowden Bridge.

The watershed is long and narrow and has an area of about 5,800 square miles. In the entire watershed there are 162,000 acres or 254 square miles that can be reclaimed. About one-half of this lies between Cowden Bridge and Carlyle. In this area under consideration Mr. Jacob A. Harman computed from his surveys that at the time of high water there were submerged 67,550 acres. The width of the valley to be reclaimed varies from one-half mile at Cowden Bridge to 3½ miles at Vandalia, and from 2 to 4 miles to points above Carlyle where it narrows to one-half of a mile. From Carlyle to New Athens the overflowed area averages 3 miles in width.

STATE OF ILLINOIS

showing Kaskaskia watershed

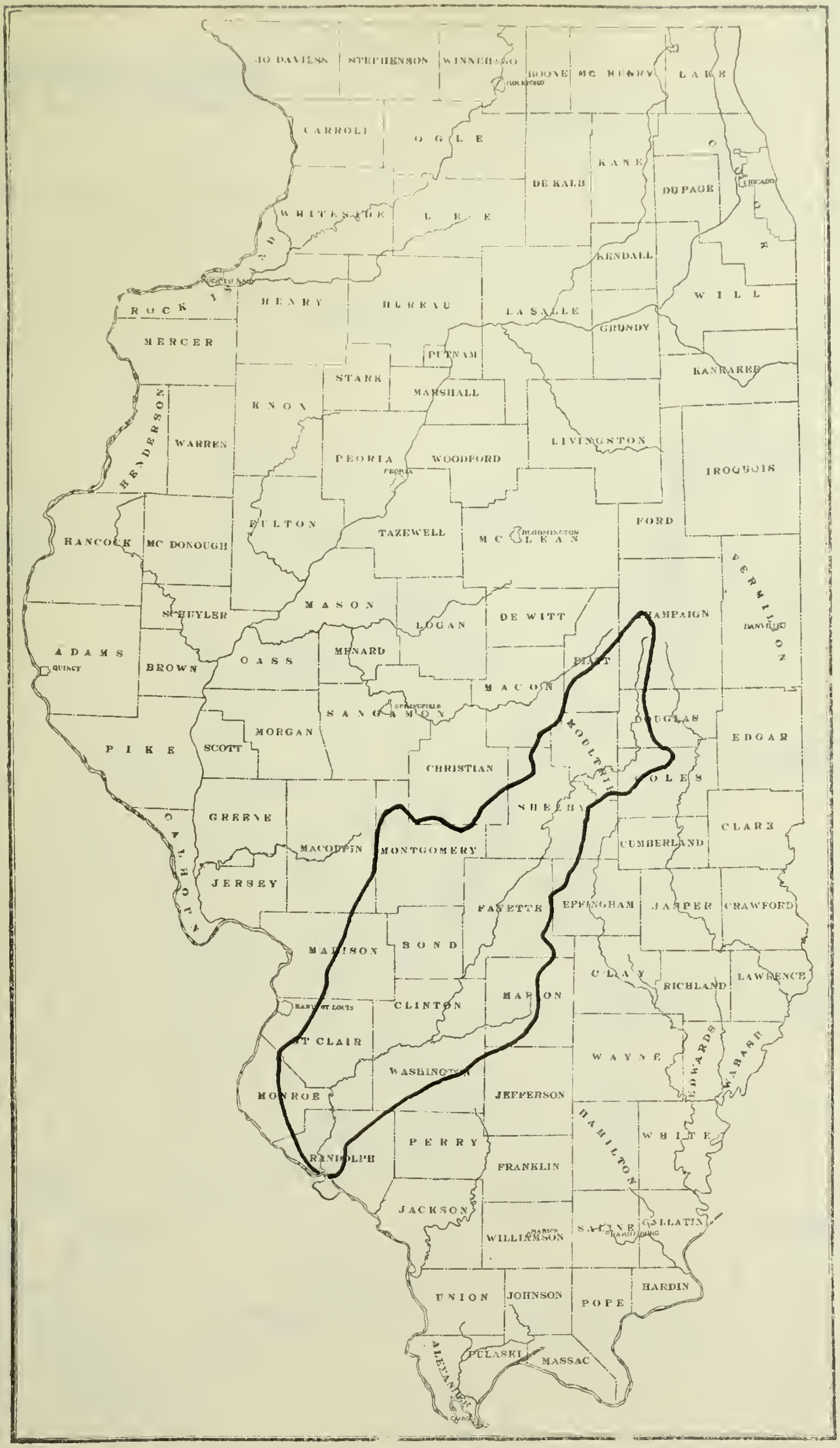
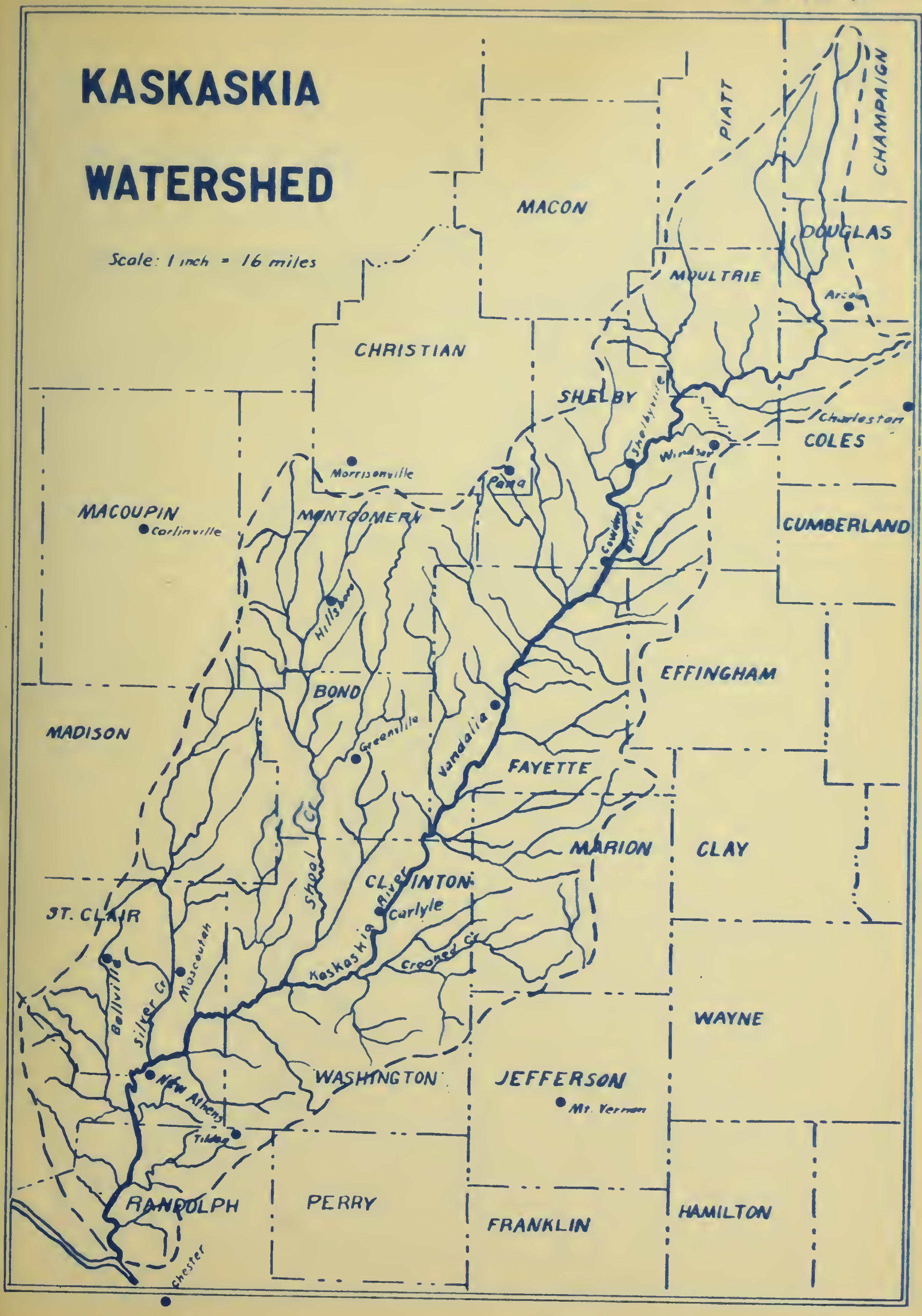
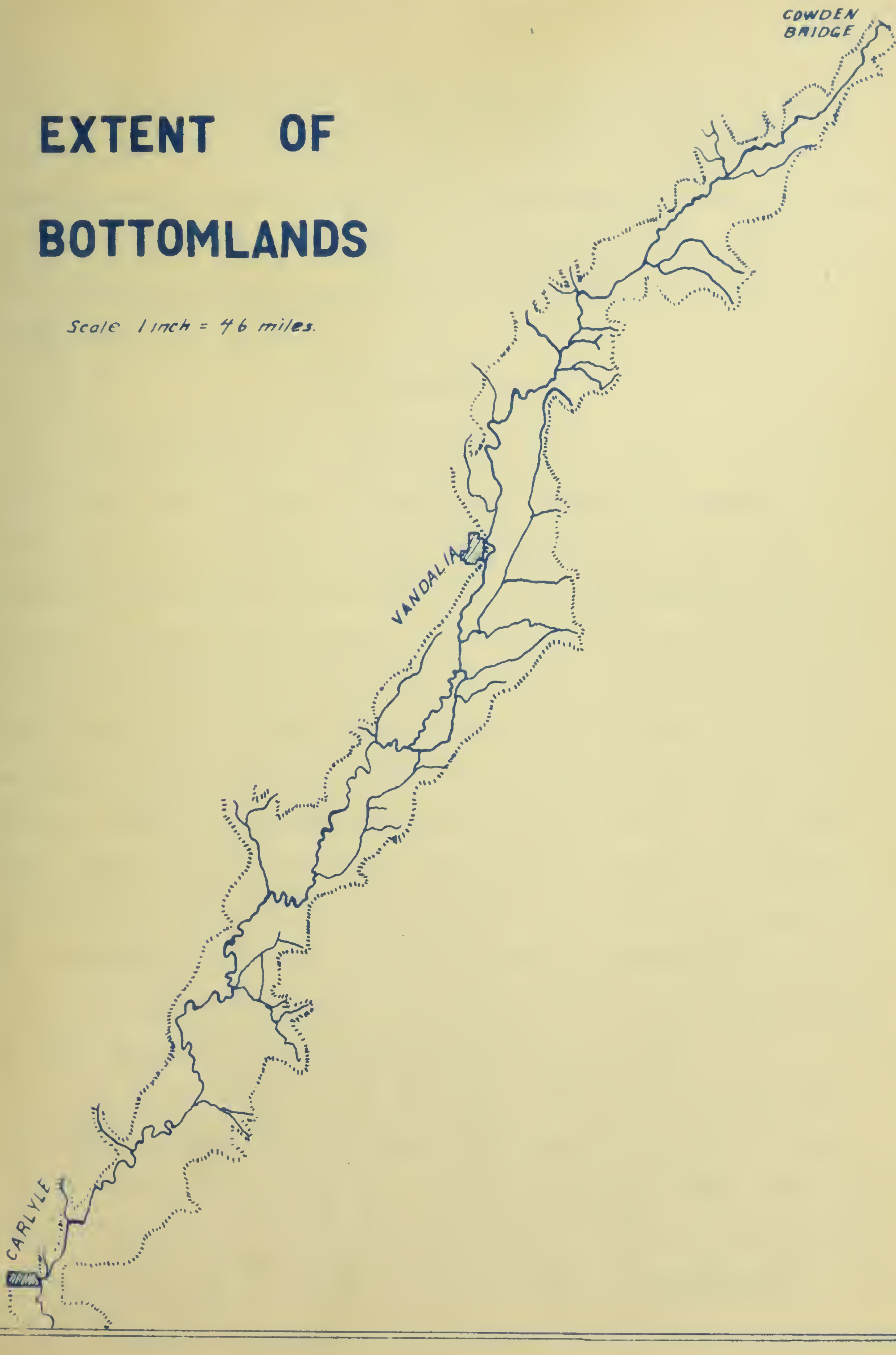


PLATE 2


KASKASKIA
WATERSHED
Scale: 1 inch = 16 miles
MACON
PIATT
CHAMPAIGN
DOUGLAS
MOULTRIE
Arcola
CHRISTIAN
SHELBY
Shelbyville
Windsor
Charleston
COLES
Morrisonville
Pana
MACOUPIN
Carlinville
MONTGOMERY
Cowden
CUMBERLAND
Hillsboro
EFFINGHAM
BOND
MADISON
Greenville
Vandalia
FAYETTE
Shoal Cr.
MARION
CLAY
CLINTON
Kaskaskia River
Carlyle
ST. CLAIR
Crooked Cr.
Belleville
Silver Cr.
Mascoutah
WAYNE
New Athens
WASHINGTON
JEFFERSON
Mt. Vernon
Tilden
RANDOLPH
PERRY
FRANKLIN
HAMILTON
Chester

EXTENT OF BOTTOMLANDS

Scale 1 inch = 4.6 miles.



The Kaskaskia River is a very crooked stream. The distance by air-line from the mouth to the source is about 180 miles, but following the sinuosities of the stream the distance is approximately 300 miles, an increase of 67%. Through the area being studied the river has a length of 90.8 miles and the proposed straightening will reduce this to 56.5 or a reduction of 37.8%.

III. PRECIPITATION.

The Kaskaskia River flows through an area of moderately heavy rain-fall. Records have been kept for many years at Cooperative Meteorological Stations under the direction of the United States Weather Bureau. The average precipitation at eleven stations in the Kaskaskia Basin for the years from 1882 to 1918 is 39.32 inches. The extremes are far from the normal. The minimum precipitation at any station was 24.80 inches at Tilden in Randolph County in 1901, and the least yearly mean was 28.03 that same year. The maximum precipitation at any station was 67.24 inches at Greenville in Bond County in 1884, and the maximum yearly mean was 52.41 inches in 1898. The yearly average for the stations near the river show a remarkable similarity. The amounts for these eight stations are within two inches of the normal for all the stations. On Plate 4 is given the annual precipitation for these stations in the Kaskaskia Valley. The first eight are close to the river and the other three are in the higher land farther from the river.

It is of interest to note that those stations close to the river have a greater precipitation than those farther away. The average of those near the river is 39.98 inches and of those farther away is 37.08 inches. The number of the stations is not great enough to give accurate results but they show in a general way the effect of a body of water on precipitation.

PRECIPITATION

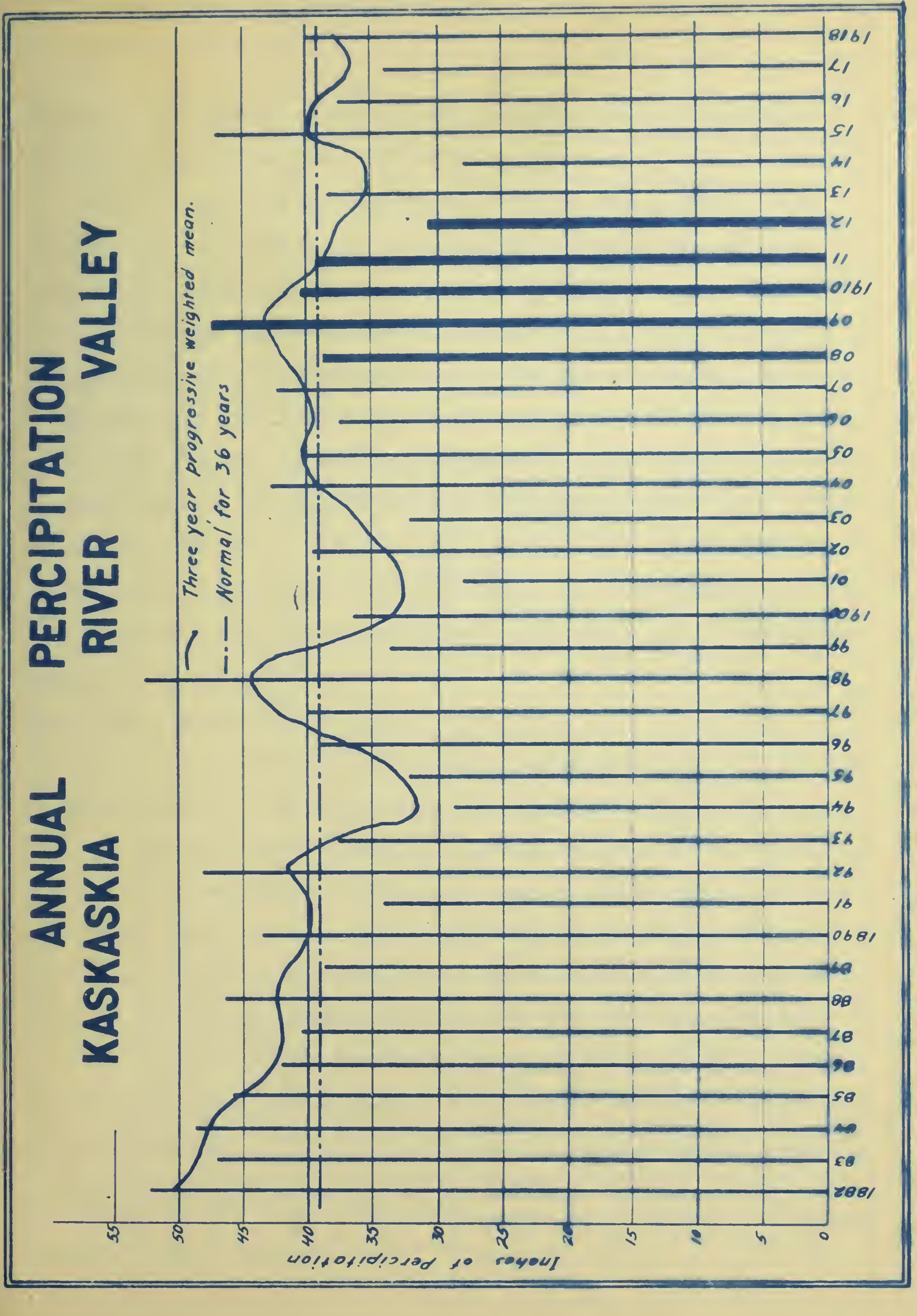
Year	Tilden Randolph Co	Mascoutah St Clair Co.	Carlyle Clinton Co.	Greenville Bond Co.	Hillsboro Montgomery Co.	Pana Christian Co.	Windsor Shelby Co	Mt Vernon Jefferson Co	Carlinville McCoupin Co	Charleston Coles Co.	Morrisonville Christian Co.	Annual Mean	3 year progressive weighted mean
1882		52.47								51.75		52.11	50.42
83		55.05		54.32		36.78			42.75	46.30		47.04	48.73
84		50.92		67.24		36.84			42.97	45.75		48.74	47.61
85		48.69		47.70		50.19			42.23	40.86		45.93	45.65
86		46.63	37.38	50.71		43.08				32.24		42.01	42.33
87	37.37	38.38	38.64	40.53		52.78				33.36		40.18	42.14
88	46.76	41.43	42.57	44.53		62.93				38.48		46.20	42.81
89	38.56	41.05	37.18	37.37		42.92				34.46		38.67	41.84
1890	47.94	45.77	34.46	39.37		49.03				40.82		43.82	40.10
91	33.71	37.40	31.63	33.57		42.33			27.64	32.28		34.08	40.00
92	45.78	43.80	41.26	46.36		63.32			48.83	46.66		48.01	41.81
93	39.81	38.57	40.55	41.12		30.06			37.12	34.22		37.35	37.91
94	29.59	28.21	27.04	31.91		27.67			30.56	27.42		28.91	31.82
95	31.55	32.61	38.93	37.14		28.67			31.54	24.21		32.11	33.03
96	38.31	41.24	44.03	42.36	32.25	31.47		41.25	41.56	45.83	31.47	38.98	37.52
97	37.53	45.11	41.10	42.87	36.86	38.36		41.03	37.81	40.86	38.36	39.99	42.84
98	56.92	57.46	59.82	52.39	54.03	44.27		56.90	51.11	43.02	50.22	52.41	44.62
99	28.73	35.11	32.16	34.20	40.15	33.50		33.66	37.22	31.35	30.70	33.68	39.03
1900	31.66	34.97	40.77	41.23	32.76	34.94		36.97	36.36	37.23	36.71	36.36	33.61
01	24.80	28.38	28.27	28.32	28.01	29.98		27.36	26.77	30.48	27.88	28.03	33.02
02	36.24	36.16	40.17	39.07	43.97	41.50		36.78	43.50	41.62	37.59	39.66	34.90
03	29.85	34.85	30.13	28.68	32.73	32.70		31.74	34.80	36.03	30.94	32.25	36.77
04	42.94	46.80	41.93	49.31	41.26	38.71	33.96	48.72	44.72	43.06	40.78	42.93	39.67
05	44.48	45.86	54.13	40.63	39.84	33.60	33.92	44.86	39.71	34.95	34.03	40.55	40.44
06	43.07	37.35	31.23	39.59	37.15	40.26	34.36	39.90	44.51	35.56	31.99	37.72	39.57
07	45.42	45.11	45.91	43.20	45.33	41.82	38.03	47.83	37.13	37.99	37.50	42.30	40.33
08	42.46	43.25	42.07	41.89	35.20	38.12	43.89	37.99	37.68	33.37	33.07	39.00	41.89
09	48.51	46.89	50.34	50.27	51.78	47.87	46.87	48.69	43.45	46.01	39.02	47.25	43.52
1910	38.42	47.33	43.62	39.27	42.84	38.78	39.52	43.22	38.82	37.71	36.69	40.57	41.95
11	37.59	35.12	41.85	44.76	37.47	42.90	45.45	35.99	35.89	38.01	38.54	39.42	38.88
12	39.36	38.93	38.64	37.66	32.60	33.34	39.85	41.84	34.07	33.42	27.31	36.09	37.56
13	46.75	38.88	38.65	40.53	43.15	36.35	34.02	44.82	31.90	33.55	36.26	38.62	35.35
14	34.65	33.21	28.32	30.16	25.54	23.16	28.12	32.68	26.35	25.40	21.10	28.07	35.46
15		50.52		49.04	50.97	42.28	48.28	42.41	48.03	42.68	44.37	47.06	40.03
16		45.04		40.01	35.09	34.46	38.89	40.59	36.32	36.72	34.12	39.92	39.23
17		33.18		27.24	29.85	36.07	37.62	34.48	28.84	40.89	37.97	34.01	36.49
18		39.12		39.16	35.51	45.66	47.80	39.15	30.20	44.67	38.84	40.01	38.01
Mean	39.24	41.64	39.60	41.49	38.45	39.77	39.37	40.39	37.46	37.84	35.45	39.32	

The records of precipitation before 1890 must be used with caution. The yearly amounts prior to 1890 at the several stations seem to be uniformly large. In other places this apparently large precipitation was investigated and it was found that observers had added ...inches of snowfall as inches of precipitation, instead of reducing the snowfall to equivalent inches of water. Whenever there occurs a record of yearly precipitation far above normal, it is well to investigate the daily records to check the snowfall data. In Plate 4 the value of the yearly amounts are given as published and are not checked for errors of observers.

There is a periodical change in the yearly amount of precipitation but this change is not regular. Many engineers have studied this change to find the cycle, but the results have been unsatisfactory. On Plate 5 is shown graphically the average yearly precipitation for these stations. The five years, 1908 to 1912 inclusive, during which the studies of run-off were made, are shown by heavier lines. In order to smooth out these values, to modify the use of the calendar year and to distribute the extremes, progressive averages for intervals of different lengths of time are used. These yearly averages have been smoothed by used of the formula for the three year progressive mean, $\frac{a + 2b + c}{4} = b'$, a, b, and c being actual values for three successive years and b' being the value of the smoothed curve for the year which had the precipitation b. Other engineers use a five year progressive mean in which $c' = \frac{a + 4b + 6c + 4d + e}{16}$.*

* Reference: Carl Peter Birkinbine, "Variations in Precipitation as Affecting Water Works" Engineering. Page 56-59.

PLATE 5



ANNUAL PERCIPITATION
KASKASKIA RIVER VALLEY
Three year progressive weighted mean.
Normal for 36 years
Inches of percipitation
0
5
10
15
20
25
30
35
40
45
50
55
1882
83
84
85
86
87
88
89
1890
91
92
93
94
95
96
97
98
99
1900
01
02
03
04
05
06
07
08
09
1910
11
12
13
14
15
16
17
1918

The three and five year progressive means coincide so closely that it does not pay to make the computation for more than three years.

It is seen from the graph that there is no regular order in these cycles. However, it can be said with reasonable certainty that for a few years after the graph has turned upward from low values the precipitation will be increasing. Likewise, after a period of heavy precipitation there will come years of lesser precipitation. It can not be said just how soon these years will come or how much less the precipitation will be. For example, since 1911 the precipitation has been below normal. In 1917 the last increase began, but even in 1918 the value of the progressive mean is still below normal. From this it may be safely said that the year 1919 will have a greater precipitation than normal. In reality it was 41.83 inches. It may also be expected that 1920 would have even more precipitation. If the rainfall continues during the year as it has started during the first months a much larger amount will be recorded.

In this connection attention may be called to the fact that the time to start agitation for drainage projects is during the years of heavy rainfall, for then the need of protection is plainly evident. Later, during the years of lesser rainfall, there will be a chance to do the work of construction. Nature does not act according to any rule that man has been able to devise, and a year of heavy precipitation may come in between two years in which the precipitation is below normal, as in 1915, 1902, 1898, and 1892.

The rains with which we are concerned in the study of this problem are not those which give large annual precipitations, but rather those which follow closely upon each other. When the soil is saturated and the streams are running bank full, an additional rain results in a greater rate of run-off.

Moreover, the Kaskaskia watershed lies in the path of frequent cyclonic storms, and a day of heavy rainfall precipitation is usually immediately preceeded or followed by days of lesser precipitation. It is seldom that a day of excess rainfall occurs singly. For this reason, rainfall above normal in any period of time is an indication of excess rainfall during a part of that time and not of a high, uniform precipitation. Therefore, it is safe to take the monthly totals as a criterion by which may be determined those months in which flooding is most apt to occur.

The mean monthly precipitation is uniform throughout the State of Illinois. The average monthly precipitation has been computed for the same stations as were used for the annual data, and the results for each station and month and their means are given on Plate 6. The mean monthly precipitation for all the stations is 3.28 inches. The maximum is 4.17 inches and occurs in May, while the minimum is 2.42 inches in December, a high value. The rainfall in each month from March to September is above the average for the year, and in May and June the quantity is greatest.

IV. STREAM FLOW AND RUN OFF.

Gaging stations were established in 1908 and 1909 at Arcola, Shelbyville, Vandalia, Carlyle and New Athens along the Kaskaskia River by the United States Geological Survey and the Internal Improvement Commission for the purpose of studying the stream flow and run-off, in preparation for drainage, flood protection, and levee construction plans. These stations were discontinued at the close of 1912. The results are published in the Report of the Internal Improvement Commission, "Surface Waters of Illinois", 1908-1910. The complete records for the five years, 1908-1912, are published in the United States Geological Survey Water Supply Papers, Nos. 245, 265, 285, 305, and 325, respectively.

MONTHLY PRECIPITATION IN THE KASKASKIA RIVER VALLEY

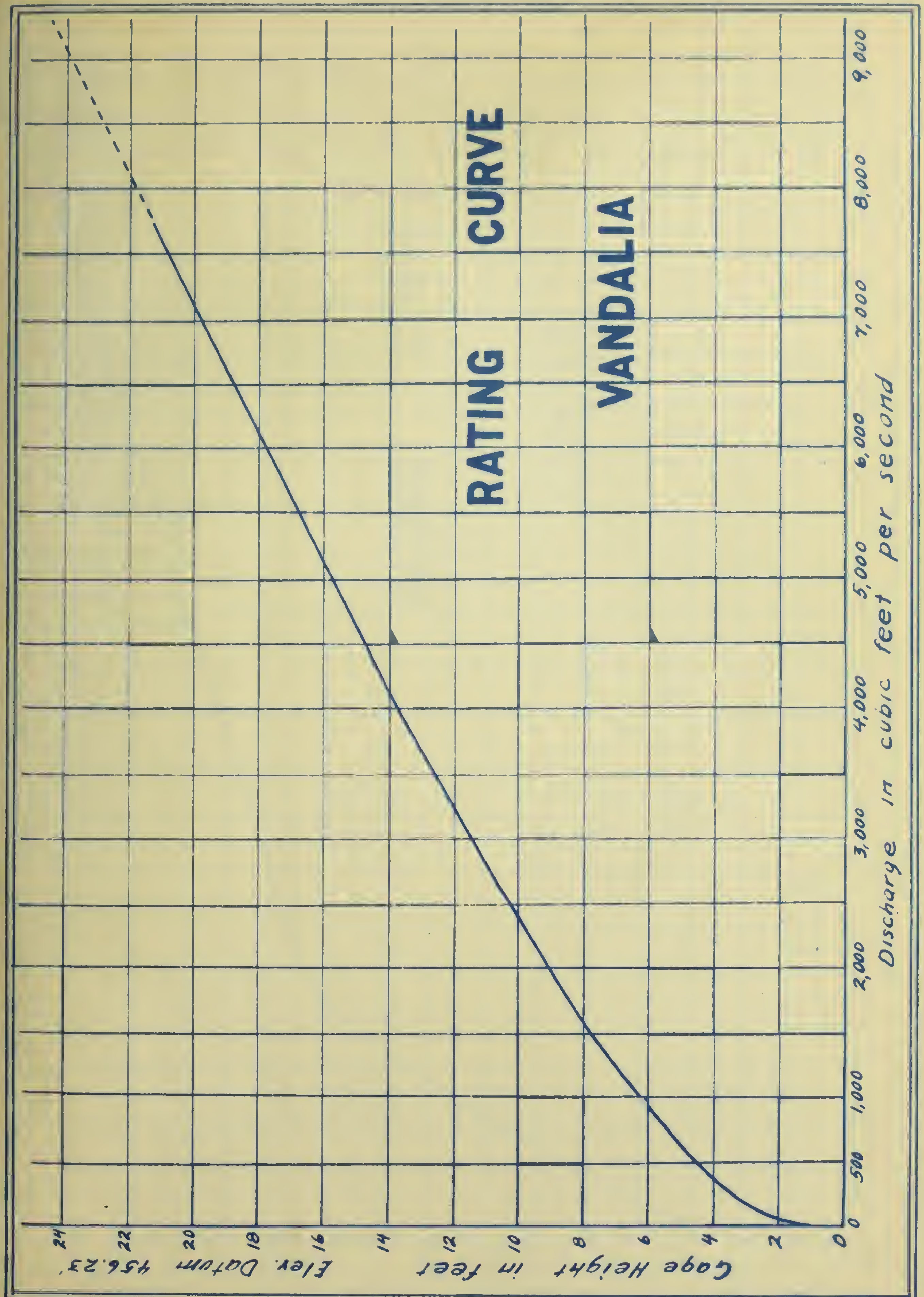
Month	Tilden Randolph Co.	Mascoutah St. Clair.Co.	Carlyle Clinton Co.	Greenville Bond Co.	Hillsboro Montgomery Co.	Pana Christian Co.	Windsor Shelby Co.	Mt.Vernon Jefferson Co.	Carlinville McCoupin Co.	Charleston Coles Co.	Morrisonville Christian Co.	Monthly Mean
Jan.	2.75	3.02	2.71	2.99	2.94	2.71	3.10	3.45	2.56	2.49	2.52	2.84
Feb.	2.66	3.37	2.66	3.10	2.37	2.77	2.22	2.90	2.53	3.12	2.05	2.70
March	3.92	3.58	3.85	3.57	3.19	3.17	3.10	4.45	3.01	3.29	2.96	3.46
April	4.08	4.05	3.98	3.93	3.64	3.64	3.85	3.29	4.19	3.21	3.47	3.76
May	3.75	4.78	4.04	4.46	4.25	4.16	4.52	3.82	4.28	3.79	3.96	4.17
June	3.39	4.43	4.42	4.71	3.93	4.42	3.30	4.06	4.08	4.04	3.82	4.06
July	3.35	3.31	3.65	3.60	3.68	3.73	4.20	3.70	3.74	3.77	3.53	3.66
Aug.	3.36	3.58	2.89	3.43	3.95	3.61	3.77	3.21	3.40	3.10	3.13	3.40
Sept.	3.45	3.66	3.57	3.64	3.56	3.57	3.88	3.61	3.44	3.07	3.06	3.50
Oct.	2.85	2.76	2.42	2.83	2.77	2.44	2.17	2.46	2.43	2.68	2.22	2.55
Nov.	3.28	3.12	3.26	3.26	2.51	3.50	2.71	2.74	2.55	3.09	2.36	2.94
Dec.	2.40	2.52	2.24	2.66	2.27	2.62	2.45	2.72	2.28	2.40	2.05	2.42
MEAN	3.27	3.51	3.31	3.51	3.25	3.36	3.37	3.27	3.21	3.17	2.93	3.28
ANNUAL	39.24	41.64	39.60	41.49	38.45	39.77	40.39	39.37	37.96	37.84	35.45	39.32

Here are given the gage heights and daily and monthly discharges for each station. A description of each station and the data obtained for the plotting of the rating curve is also given.

The river banks, as is the case with all silt bearing streams are higher than the lands farther back from the river. This is due to the deposition of silt as soon as the water leaves the swift current to spread out over the flooded area. The carrying capacity of water increases as the fifth power of the velocity, and the size of the particles carried varies as the sixth power of the velocity.* A small reduction in the velocity makes a decided change in the quantity of silt that can be carried by a stream. IN this way the banks are built up year after year at each succeeding overflow. In the Kaskaskia valley the banks are from one to three feet higher than the lands lying between the river and the bluffs, so that an increase above bank full stage means practically inumdation, or at least the closing of the outlets of the drains for the entire flooded area. At time of high floods the low lands are covered with water to a depth of 10 feet.

The Kaskaskia River frequently overflows its banks and completely covers all the bottom lands. Farming operations on these lands are impossible, for the river is out of its banks almost every spring and the farmers will not take the risk of losing their seed. The soil is the characteristic silt-loam of the bottom lands and is extremely fertile. When it is protected from overflow it will produce abundant crops. On Plate 9 are shown the drainage hydrographs of the Kaskaskia River. These hydrographs show the range of gage heights for the five stations during the five years from 1908 to 1912. The river was over its banks every spring. In 1911 the spring floods were not excessive, but a big flood occured in the fall. These periods of overflow are shown for each month on Plate 10. At Vandalia during the five years the

* Reference: J. G. Mosier, "Soil Physics and Management," page 33.


RATING CURVE
VANDALIA
Discharge in cubic feet per second
0
500
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
Gage Height in feet
Elev. Datum 456.23'
0
2
4
6
8
10
12
14
16
18
20
22
24

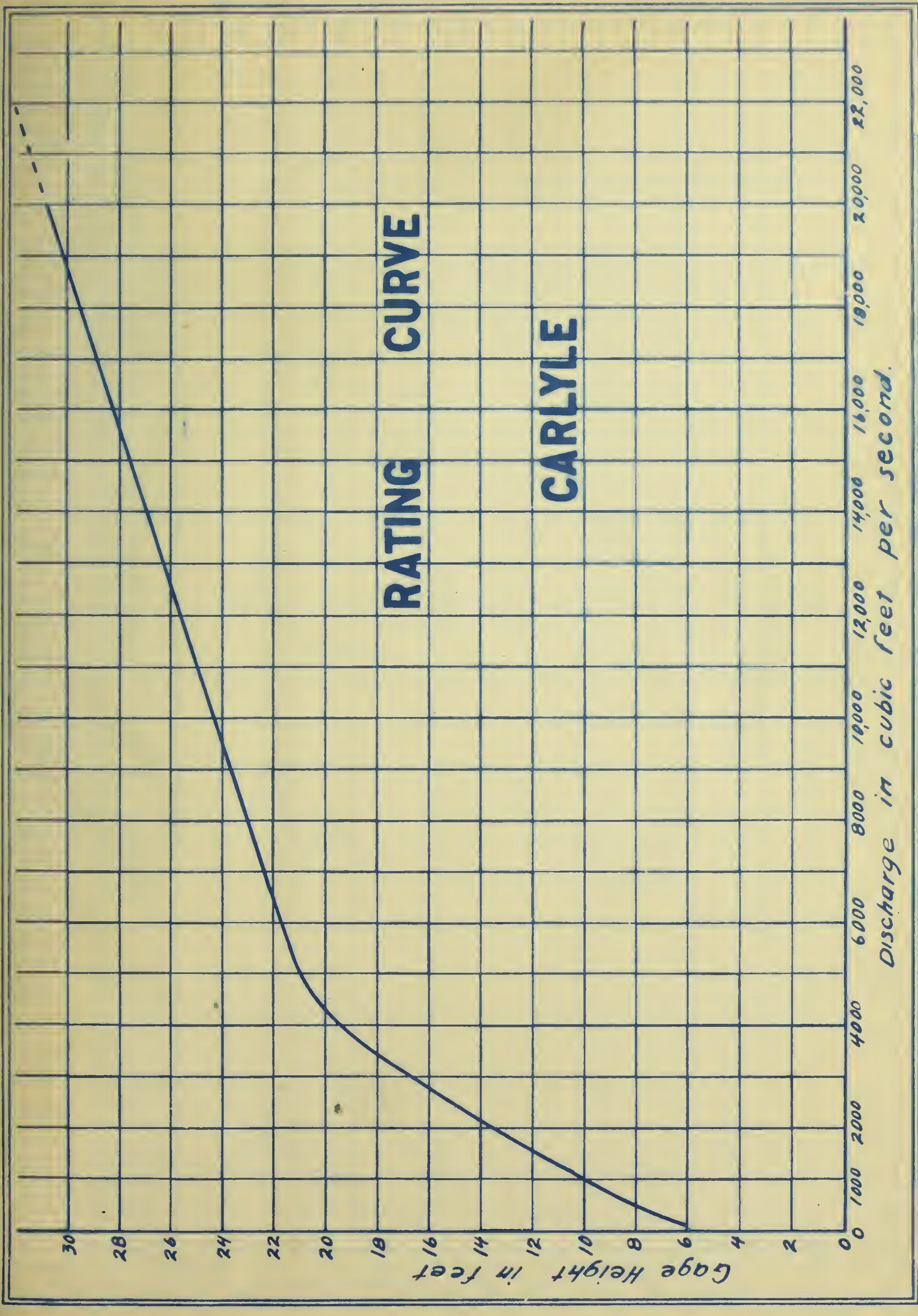
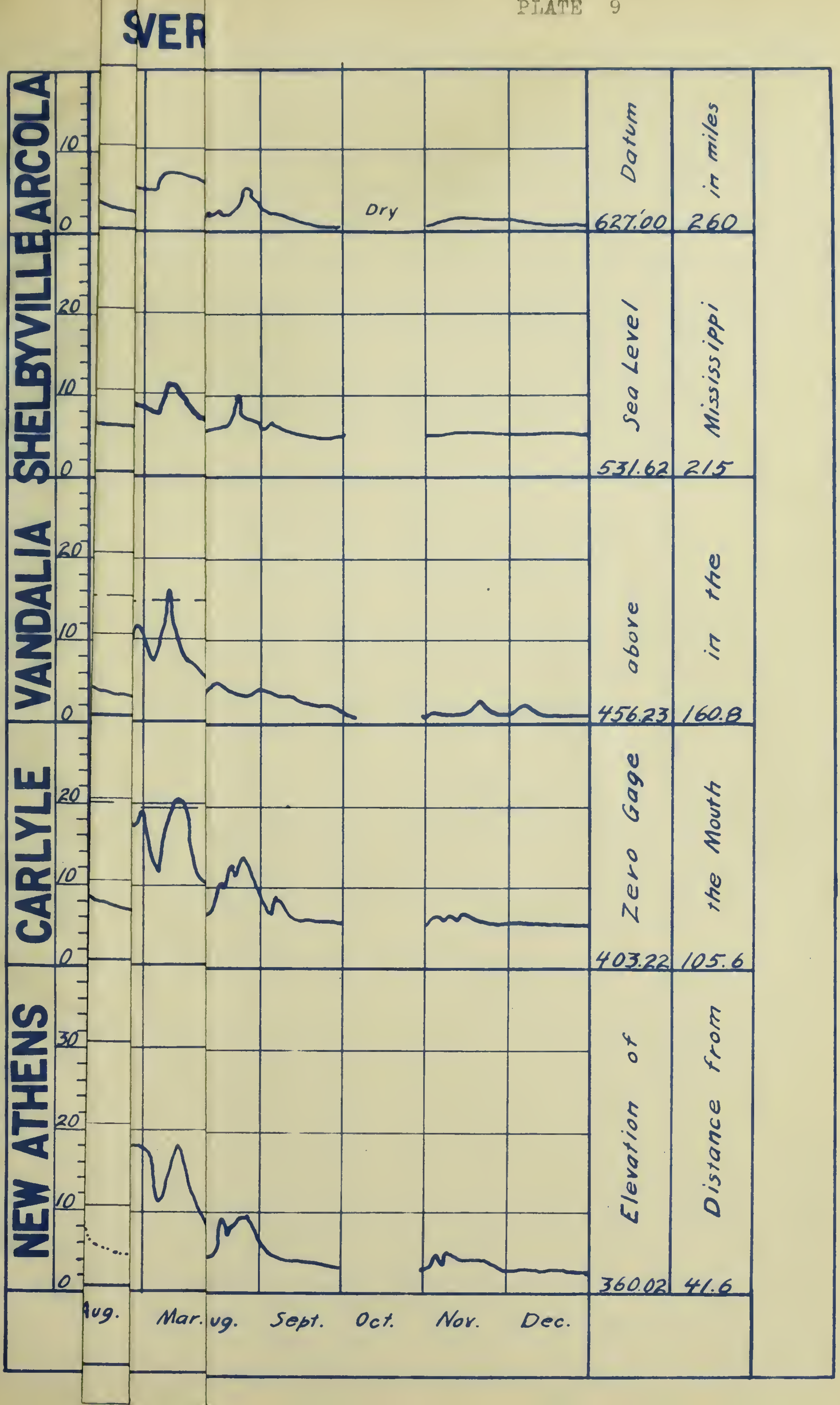

RATING CURVE
CARLYLE
Discharge in cubic feet per second.
0
1000
2000
4000
6000
8000
10,000
12,000
14,000
16,000
18,000
20,000
22,000
Gage Height in feet
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30

PLATE 9


SVER
ARCOLA
SHELBYVILLE
VANDALIA
CARLYLE
NEW ATHENS
Dry
Elevation of Zero Gage above Sea Level Datum
Distance from the Mouth in the Mississippi in miles
627.00
260
531.62
215
456.23
160.8
403.22
105.6
360.02
41.6
Aug.
Mar.
ug.
Sept.
Oct.
Nov.
Dec.

RIVER STAGE HYDROGRAPHS OF THE KASKASKIA RIVER IN ILLINOIS

DAYS PER MONTH OF OVER-FLOW IN THE KASKASKIA RIVER VALLEY.

Vandalia, Fayette County

Bank full stage, gage 15.0'

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1908	..	..	15	8	17	..	..	..	..	..	..	..
1909	..	8	2	23	2	1	9	..	..	..	..	..
1910	5	2	5	..	7	..	2	..	..	..	..	..
1911	..	..	1	3	2	..	..	..	5	11	..	..
1912	..	4	20	12	2	..	..	..	..	..	..	..
Total	5	14	43	46	30	1	11	..	5	11	..	..

Carlyle, Clinton County

Bank full stage, gage 13.5'

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1908	..	16	21	12	30	...	..	..	..	..	..	..
1909	..	7	14	20	12	3	12	..	..	..	..	3
1910	15	1	9	..	7	5	2	..	..	5	..	..
1911	..	..	4	13	7	..	..	..	..	17	5	..
1912	..	3	25	23	13	..	..	..	..	..	..	..
Total	15	29	73	68	69	8	14	..	..	22	5	3

New Athens, St.Clair County

Bank full stage, gage 20.0'

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1908	..	16	22	8	30	3	..	..	..	..	..	..
1909	..	8	18	20	8	..	9	..	..	..	..	..
1910	13	..	14	..	6	..	..	..	9	9	..	..
1911	..	..	..	4	10	..	..	..	..	15	..	..
1912	..	2	29	27	16	5	..	..	..	..	..	..
Total	13	26	83	59	70	8	9	..	9	24	..	..

river was out of its banks 166 days or an average of 35.2 days per year. At Carlyle the conditions are much worse and the yearly average of overflow was 61.2 days per year. These average per month, as follows: January, 3; February, 6; March, 15; April, 14; May, 14; and small amounts for the remaining months.

Plates 6 and 7 are rating curves for Vandalia and Carlyle. At any point on the curve the ordinate is the gage height of the river and the abscissa is the discharge in cubic feet per second. By means of these rating curves the gage height of the river is expressed in units of discharge. In matters of preliminary study in drainage, it is of greater importance to know the stage of the river than of the amount of discharge; and for this reason the ensuing curves are made in terms of the gage height. These rating curves are provided so that the discharge may be expressed in cubic feet per second for each gage height.

The number of days at which each gage height occured have been summed up so as to show the duration of each height. The results of this are given for Vandalia and Carlyle on Plates 11 and 12, and these data are plotted on Plate 13. These river-stage duration-curves show the days duration for each gage height. This duration curve must not be confused with the ordinary duration curve, for in the curve presented here the duration of each river stage is shown, while in the ordinary curve it is the duration of the rate of flow that is shown. This accounts for the difference in shape. At any point in the curve the ordinate is the gage height and the abcissa the number of days in the year in which that stage or greater may be expected to occur. The curves are particularly useful in showing the relative periods of overflow. All these data are the result of the five-year measurements.

The most serious flood in the Kaskaskia vallyy occured in May 1908.

DATA FOR

RIVER STAGE DURATION CURVE

AT VANDALIA

Gage	1908	1909	1910	1911	1912	Total	Days	Duration
0 - 1	0	0	0	4	30	34	6.8	365.4
1.- 2	161	55	0	58	61	334	66.8	358.6
2 - 3	28	49	37	31	31	176	35.2	291.8
3 - 4	26	22	59	13	35	155	31.0	256.6
4 - 5	15	32	78	7	31	162	32.4	225.6
5 - 6	8	37	48	22	31	146	29.2	193.2
6 - 7	13	26	32	35	23	129	25.8	164.0
7 - 8	11	16	27	36	17	107	21.4	138.2
8 - 9	13	17	19	40	23	112	22.4	116.8
9 -10	9	18	10	30	13	80	16.0	94.4
10 -11	8	8	8	15	9	48	9.6	78.4
11 -12	4	12	6	15	7	44	8.8	68.8
12 -13	7	11	3	14	6	41	8.2	60.0
13 -14	4	8	12	9	5	38	7.6	51.8
14 -15	5	9	5	15	7	41	8.2	44.2
15 -16	7	7	4	5	6	29	5.8	36.0
16 -17	11	12	8	8	2	41	8.2	30.2
17 -18	15	14	4	2	7	42	8.4	22.0
18 -19	12	9	4	3	9	37	7.4	13.6
19 -20	6	1	2	2	12	23	4.6	6.2
20 -21	2	2	0	2	1	7	1.4	1.6
21 -22	1	0	0	0	0	1	.2	.2

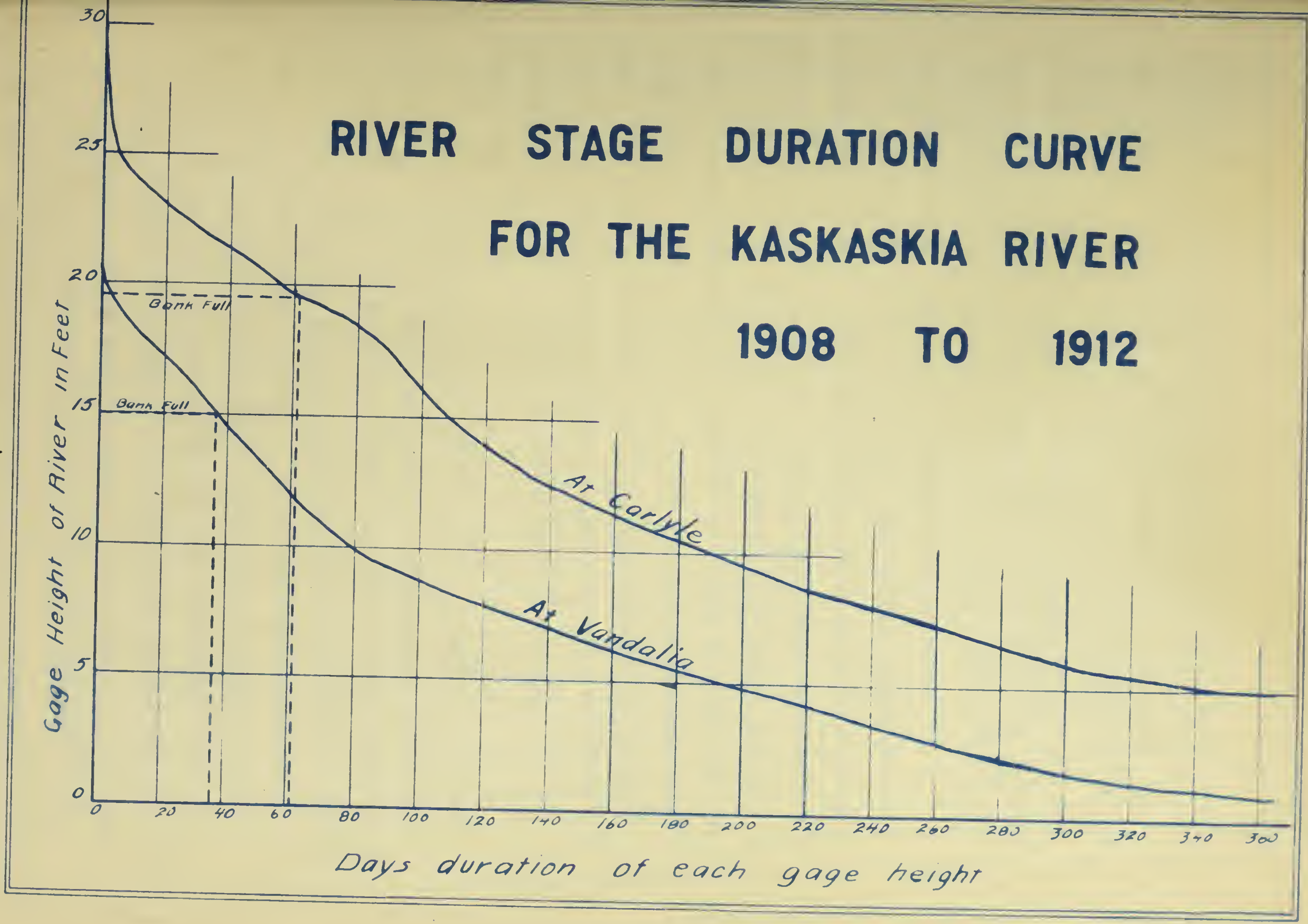
DATA FOR

RIVER STAGE DURATION CURVE

AT CARLYLE

Gage	1908	1909	1910	1911	1912	Total	Days	Duration
5 - 6	123	59	...	65	77	324	64.8	365.4
6 - 7	27	42	33	28	40	170	34.0	300.6
7 - 8	16	18	59	13	15	121	24.2	266.6
8 - 9	29	25	59	11	32	156	31.2	242.4
9 - 10	12	26	44	8	20	110	22.0	211.2
10 - 11	10	20	34	21	29	114	22.8	189.2
11 - 12	9	19	21	25	21	95	19.0	166.4
12 - 13	13	16	17	23	14	83	16.6	147.4
13 - 14	6	12	14	17	14	63	12.6	130.8
14 - 15	8	7	8	19	8	50	10.0	118.2
15 - 16	7	9	9	17	4	46	9.2	108.2
16 - 17	6	9	5	15	3	38	7.6	99.0
17 - 18	7	10	7	14	3	41	8.2	91.4
18 - 19	10	13	6	24	12	65	13.0	83.2
19 - 20	7	21	10	26	14	78	15.6	70.2
20 - 21	4	17	9	12	7	49	9.8	54.6
21 - 22	15	17	18	14	9	73	14.6	44.8
22 - 23	18	7	6	1	14	46	9.2	30.2
23 - 24	28	4	3	2	13	50	10.0	21.0
24 - 25	4	9	3	3	12	31	6.2	11.0
25 - 26	1	5	..	2	5	13	2.6	4.8
26 - 27	1	..	..	3	..	4	.8	2.2
27 - 28	1	..	..	2	..	3	.6	1.4
28 - 29	1	..	..	..	..	1	.2	.8
29 - 30	1	..	..	..	..	1	.2	.6
30 - 31	2	..	..	..	..	2	.4	.4

PLATE 13


RIVER STAGE DURATION CURVE
FOR THE KASKASKIA RIVER
1908 TO 1912
At Carlyle
At Vandalia
Bank Full
Bank Full
Gage Height of River in Feet
Days duration of each gage height
0
5
10
15
20
25
30
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360

At that time all the bottom lands were flooded to a depth of from 3 to 10 feet. Levees broke and districts thought protected were inundated. At Carlyle the river was out of its banks for 42 days. The precipitation over the valley was heavy and uniform. On Plate 14 is listed the rainfall from April 21st. to June 5th. at six stations close to the river. The discharge in cubic feet per second at Carlyle is given on Plate 15 for each of these days. Then on Plate 16 these data are presented graphically.

During the six days from April 22nd. to 27th. inclusive an average of 2.50 inches of rain fell, and this was enough to force the river out of its banks. Then on the 3rd. of May the rains began again and in six days rainfall the average of the six stations was 6.19 inches, with 5.73 inches of this in the middle four days. In three days the river rose from a gage height of 23.1 feet to 30.8 feet, or more than 10 feet above its banks. This was the most serious flood ever experienced in the Kaskaskia valley. After this period of excessive rainfall, the rains continued, but in small amounts. The river was not inside of its banks again until the first of June.

The heavy rains came on the 4th, 5th, 6th, and 7th. of May and the flood was not at its crest until the 9th. showing that it takes about four days for the flood waters to accumulate and fill the wide flooded and storage area. The little rains in the middle of the month fell on saturated ground, and these caused a high rate of run-off and the high flood-flow of the river was maintained for many days. On the 30th. and 31st. of May no rain fell and the river quickly returned to within its banks. On the 3rd. of June an average of 0.31 inches of rain fell, but the ground absorbed most of it, and the run-off was small and gradual. The discharge at the crest of the flood was 7.37 cubic feet per second per square mile, while at bank

Record of Daily Precipitation over the Kaskaskia Watershed

During the May 1908 Flood

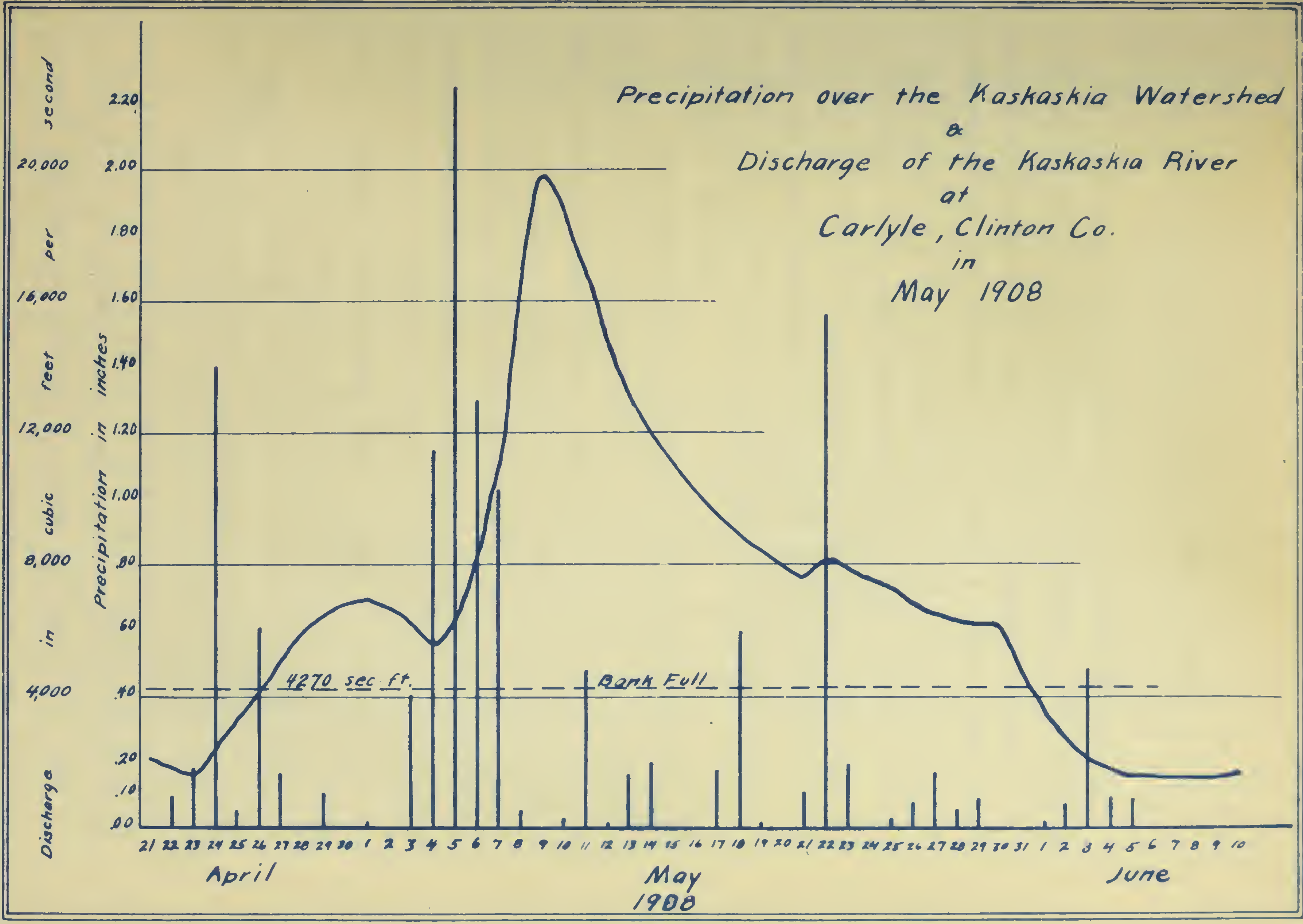
Date 1908		Carlyle	Greenville	Mascoutah	Hillsboro	Pana	Windsor	Average
April	21	....	....	....	....	....	....	....
	22	....	....	0.60	....	....	....	0.10
	23	0.50	0.19	....	0.08	0.06	0.24	0.18
	24	1.20	1.17	1.52	1.25	1.68	1.50	1.39
	25	0.25	....	....	....	0.03	T	0.05
	26	0.55	0.92	1.02	0.04	0.60	0.51	0.61
	27	....	....	....	0.65	0.12	0.23	0.17
	28	....	....	....	....	T	....	....
	29	0.25	0.14	0.26	T	T	....	0.11
	30	....	....	....	....	....	....	....
May	1	....	T	....	....	T	0.09	0.02
	2	....	....	....	....	....	....	....
	3	0.25	0.53	0.52	....	0.67	0.49	0.41
	4	0.35	0.04	0.04	1.35	0.96	4.10	1.14
	5	2.00	1.31	2.86	1.48	2.36	3.50	2.25
	6	1.75	2.70	1.54	0.55	0.87	0.37	1.30
	7	0.70	0.48	0.50	1.88	1.20	1.50	1.04
	8	....	....	....	0.15	0.09	0.05	0.05
	9	....	....	T	....	....	....	....
	10	0.15	....	....	....	....	....	0.03
	11	....	0.23	0.25	0.45	0.91	1.00	0.48
	12	....	....	....	0.12	....	....	0.02
	13	0.10	0.29	0.14	....	0.27	0.18	0.16
	14	0.20	0.16	0.52	0.18	0.09	0.04	0.20
	15	....	....	....	....	....	....	....
	16	....	....	....	....	....	....	....
	17	0.30	0.14	0.60	....	....	....	0.18
	18	0.50	0.74	0.44	0.46	0.96	0.40	0.60
	19	....	....	....	0.06	....	0.05	0.02
	20	....	....	....	....	....	....	....
	21	....	0.68	....	....	....	....	0.11
	22	3.25	0.95	2.21	....	1.68	1.42	1.56
	23	....	....	....	1.20	....	....	0.20
	24	....	....	....	....	....	....	....
	25	....	0.13	....	....	....	0.02	0.03
	26	0.25	0.22	....	....	....	....	0.08
	27	0.08	....	0.90	....	0.04	T	0.17
	28	....	0.23	....	0.15	....	....	0.06
	29	....	....	0.15	0.25	0.11	0.05	0.09
	30	....	....	....	....	....	....	....
	31	....	....	....	....	....	....	....
June	1	....	....	....	....	0.04	....	0.01
	2	....	....	0.27	0.15	....	T	0.07
	3	1.00	....	0.78	....	0.05	0.05	0.48
	4	0.40	....	....	0.22	....	....	0.10
	5	....	....	....	0.53	....	....	0.09
	6	....	....	....	....	....	....	....
Total 45 days		14.13	11.25	15.12	11.20	12.79	15.79	
Average per day		.314	.250	.360	.249	.284	.361	

DISCHARGE OF THE KASKASKIA RIVER AT CARLYLE

DURING THE MAY 1908 FLOOD.

APRIL	21	2140 sec.-ft.		MAY	14	11900 sec.-ft.
	22	1790			15	11000
	23	1650			16	10200
	24	2570			17	9610
	25	3470			18	9000
	26	4220			19	8550
	27	5360			20	[illegible]090
	28	6110			21	7830
	29	6570			22	8240
	30	6870			23	7940
MAY	1	6870			24	7630
	2	[illegible]720			25	7330
	3	6270			26	6870
	4	5510			27	6570
	5	6270			28	6420
	6	8240			29	6270
	7	11000			30	5270
	8	17400			31	4660
	9	19300		JUNE	1	[illegible]340
	10	18700			2	2640
	11	16900			3	1940
	12	14600			4	1710
	13	13100			5	1540

PLATE 16



Precipitation over the Kaskaskia Watershed
&
Discharge of the Kaskaskia River
at
Carlyle, Clinton Co.
in
May 1908
Discharge in cubic feet per second
20,000
16,000
12,000
8,000
4,000
Precipitation in inches
2.20
2.00
1.80
1.60
1.40
1.20
1.00
.80
60
.40
.20
.10
.00
4270 sec. ft.
Bank Full
21 22 23 24 25 26 27 28 29 30 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 1 2 3 4 5 6 7 8 9 10
April
May
1908
June

full stage the discharge can be but 1.59 cubic feet per second per square mile.

This measured rate of run-off is much less than has been observed under similar rainfall conditions in like territory. This had led to an extensive investigation of the rate of run-off necessary for which provision must be made when the bottom lands within the Kaskaskia valley shall be leveed against overflow. These lands will then be no longer available for the storage of the flood waters which come from the adjacent hills and high lands, and which must be carried directly through the channels and between the levees substantially in the time in which it reaches the valley, instead of prolonging the period of high water for a number of days by storage over a wide area.

Harman made extensive surveys and computations to determine this rate of run-off when no storage was used. He measured the areas submerged between Carlyle and Cowden Bridge at each foot of gage height, and from the increase and decrease in storage during the May 1908 flood he computed that the water entered the valley, 2700 square miles in area, above Carlyle at a maximum rate of 25 cubic feet per second per square mile, which is equivalent to about one inch of rainfall in 24 hours. This rate of run-off compares favorably with the formula given by Murphy. The constants were changed to fit the conditions of the Kaskaskia valley and the formula became $q = \frac{30,000}{M+200} + 15$, in which q is the run-off in cubic feet per second per square mile, and M is the area of the water shed in square miles.

The discharge measurements show an average rate of run-off of about 10 cubic feet per second per square mile for flood flow. The channels of the Kaskaskia have constructed for themselves natural cross-sections having a capacity of about 3 1/3 cubic feet per second per square mile. This

compares with the formula $q = 33\sqrt[3]{\frac{I}{M}}$ for an area of 1,000 square miles.

The carrying capacity of an open channel is computed from the formula $v = c\sqrt{rs}$ in which v is the velocity of flow, c is a constant determined by Kutters formula, r is the hydraulic mean radius obtained by dividing the area of cross-section by the wetted perimeter, and s is the sine of the slope. Kutters formula gives a value for c in terms of r, s, and n, a roughness factor. This factor, n, must be estimated for each channel. In new work, while the channel is clear and straight n is 0.030 and may even fall as low as 0.025; but as the channel fills up with brush, and debris, and the stream begins to meander, the value of n increases. If the discharge, cross-section area, slope and width are known the formula may be worked backward and the actual value of n computed.

V. DETERMINATION OF N.

The data for the rating curves at each station furnish the data for the computation of n. When the discharge and the cross-section area are known, the velocity can be computed by dividing and this value with the hydraulic mean radius and the slope gives the value of c. Then the Kutter's formula:-

$$c = \frac{41.6 + \frac{.00281}{s} + \frac{1.811}{n}}{1 + \left(41.6 + \frac{.00281}{s}\right)\frac{n}{\sqrt{r}}}$$

the value of n can be computed by substituting all the known values of the other factors. The results of these computations are shown on Plate 17.

These figures plainly show the effect of the winding course on the value of n. The straightening of the stream will lower the value of n and thus will increase the discharge.

DETERMINATION OF THE ROUGHNESS COEFFICIENT n

At Vandalia

Date	Width	Area	Gage	Discharge	r	slope	v	c	n
1908									
Mar. 19	128	1510	10.1	2400	10.5	0.0001407	1.59	41.4	0.0623
" 20	128	1430	9.6	2130	10.0	"	1.49	39.6	.0648
Apr. 30	151	1890	12.9	3600	10.8	"	1.91	49.0	.0518
1909									
Feb. 20	156	2440	15.78	5330	14.2	"	2.18	48.8	.0562
Mar. 16	132	1150	7.26	1340	8.2	"	1.17	34.4	.0712
May 13	151	2100	13.86	4100	12.7	"	1.95	46.3	.0580
1910									
June 4	126	1130	8.05	1570	8.4	"	1.39	40.5	.0595
		Average n at Vandalia							.0605

At Carlyle

Date	Width	Area	Gage	Discharge	r	slope	v	c	n
1908									
Mar. 23	196	1770	16.7	2830	8.[illegible]	0.0001327	1.60	47.2	0.0[illegible]
May 4	512	3770	21.35	5360	7.1	"	1.45	46.7	.0530
1909									
Feb. 22	514	3660	20.70	4710	6.8	"	1.29	47.0	.05[illegible]
Mar. 15	[illegible]	4480	[illegible].29	7110	8.1	"	1.48	[illegible].3	[illegible]
May 7	177	1510	15.76	2640	7.8	"	1.7[illegible]	57.5	[illegible]
1910									
May 27	522	3510	[illegible]	4710	6.5	"	1.[illegible]	4[illegible].8	[illegible]
May 29	[illegible]	3910	21.17	5310	7.1	"	1.36	[illegible]	[illegible]
		Average n at Carlyle							[illegible]

At New Athens

Date	Width	Area	Gage	Discharge	r	slope	v	c	n
1909									
Nov. 16	259	3310	16.59	7020	12.9	0.0000726	2.12	69.3	0.0[illegible]80
Dec. 1	213	1490	6.54	1930	6.7	"	1.29	58.4	.0[illegible]92
1910									
Mar. 23	205	1[illegible]0	7.45	1400	5.7	"	1.15	56.7	.0[illegible]75
June 1	[illegible]	4090	19.77	9570	15.0	"	2.34	71.0	[illegible]
Dec. 10	195	945	[illegible].96	920	[illegible].7	"	0.97	52.[illegible]	[illegible]
		Average n at New Athens							[illegible]

VI. Effect of Straightening

The general conditions of the overflowed portion of the Kaskaskia valley between Carlyle and Cowden Bridge are as follows. The width of the overflowed area from Carlyle to Vandalia is almost uniformly between two and one-half and three and one-half miles. From Vandalia to within about six miles of Cowden Bridge the width is from two to three miles, and thence to Cowden Bridge the width is from one-half to one mile. For convenience in the study of the effect of straightening, the river is divided into two parts: Carlyle to Vandalia; and Vandalia to Cowden Bridge. These two sections are drawn on PLATES 18 and 19, respectively.

The depth of the natural channel of the Kaskaskia River is such that if the water could be kept at an ordinary low-water stage, complete drainage by ditching alone could be furnished to all the overflowed lands. The problem then becomes one of finding and substituting plans by which the equivalent of an ordinary low-water-stage outlet may be provided. This might be accomplished by the construction of a larger and deeper channel, sufficient to carry all the floods between the banks. Such an undertaking would require the expenditure of such a vast sum of money that the benefits would not be equal to the cost. Any plan to be adopted must offer financial and sanitary benefits equal to or greater than the costs.

The present channel of the stream is very crooked, frequently passing partially or entirely across the flood plain of the valley and with numerous bends and loops. If the channel were straightened it would be shortened and there would be less obstruction to the flow of water. The shortened channel would give a greater slope and this would increase the velocity. The straight channel would reduce the roughness coefficient and this would also increase the velocity. Since the course is shorter the time of flow will be

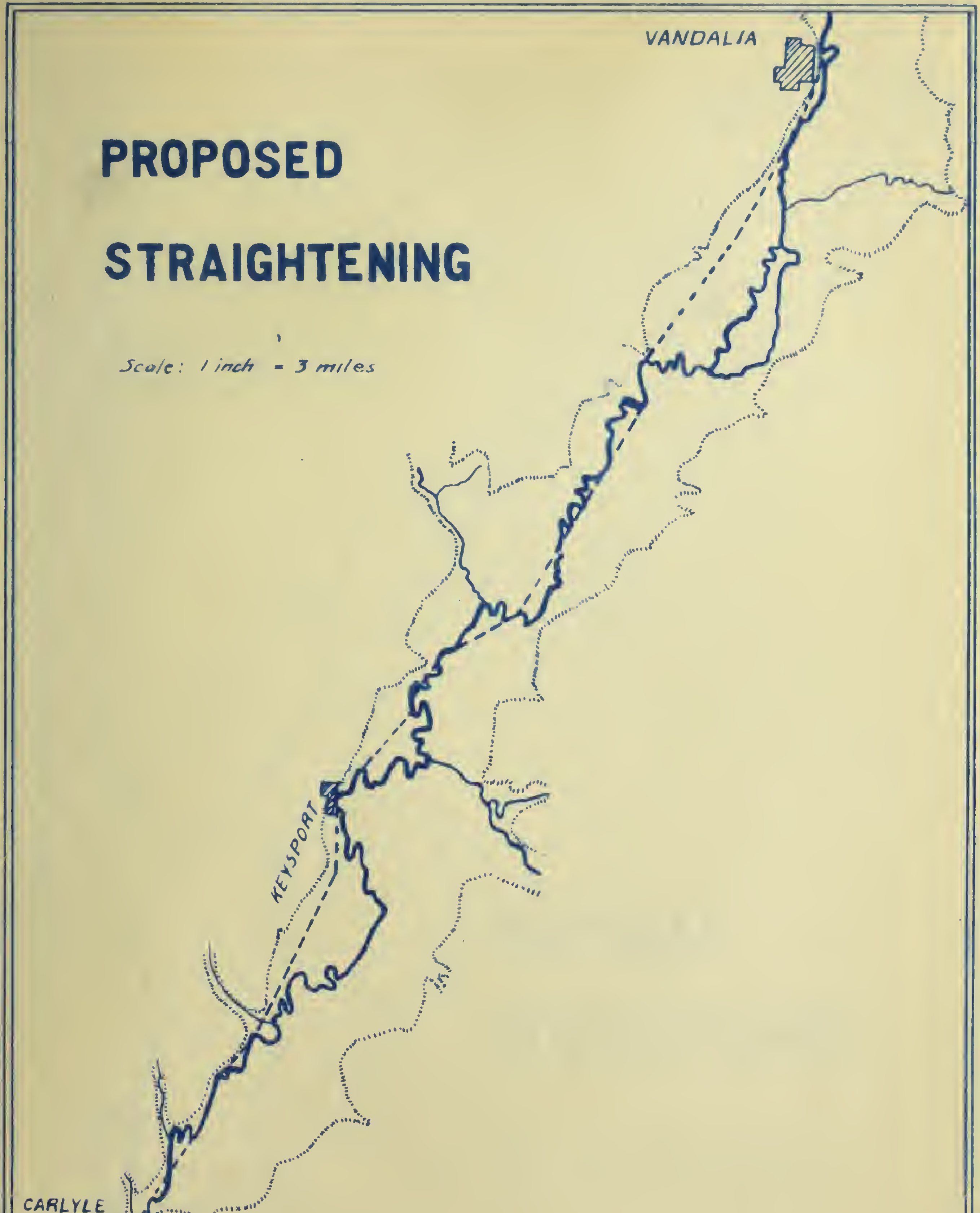
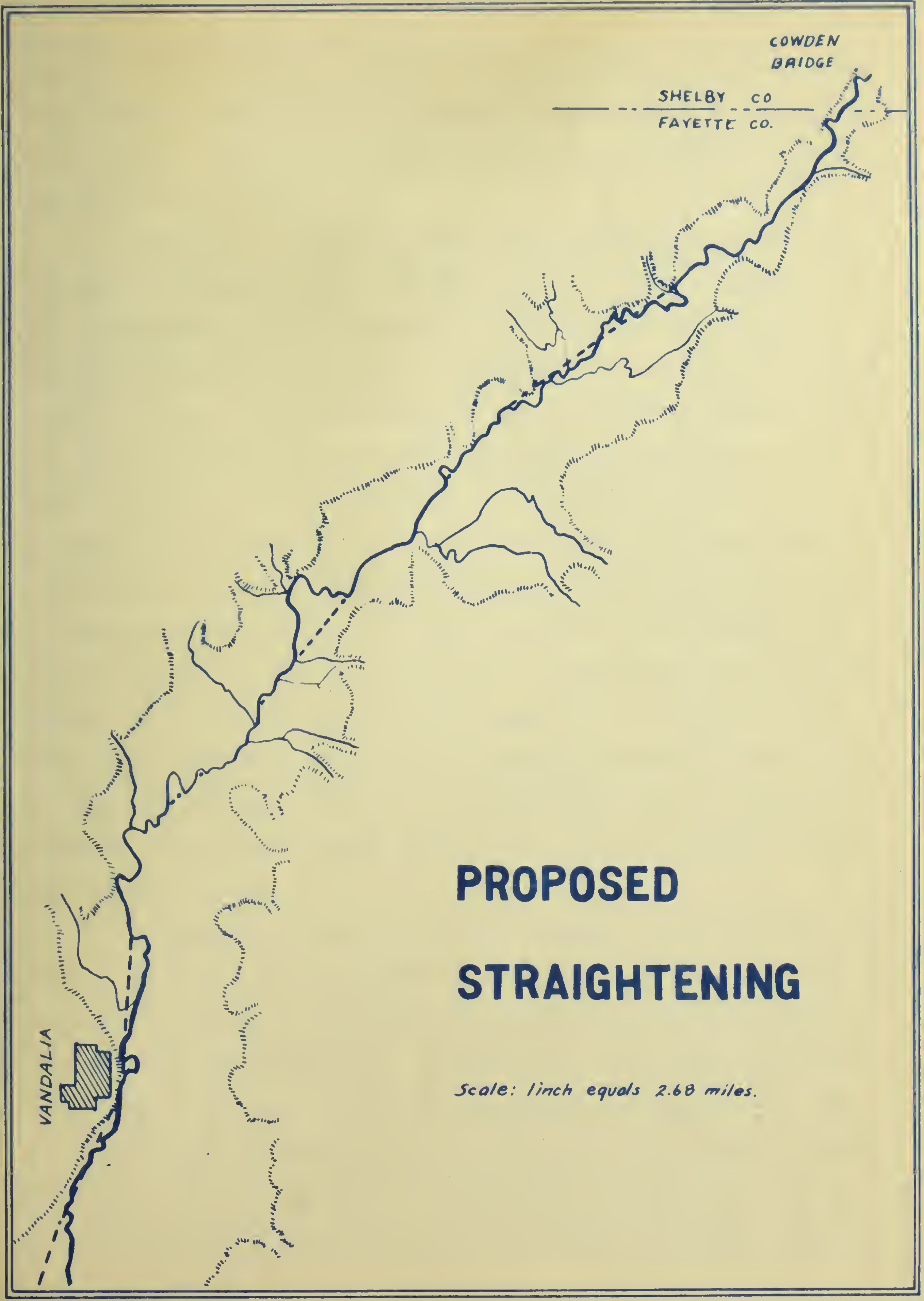

PROPOSED
STRAIGHTENING
Scale: 1 inch = 3 miles
VANDALIA
KEYSPORT
CARLYLE

PLATE 19



PROPOSED STRAIGHTENING

less than before. Therefore, with the velocity increased by the greater slope and the smoother channel the carrying capacity of the proposed channel will be so much greater than that of the former stream that the flooding of adjacent lands will be less frequent.

The amount of straightening that can be economically effected will not be here discussed because of the fact that the data are insufficient. The plans which already have been prepared are taken and the effect of this suggested straightening is studied. From Carlyle to Vandalia almost a median route is followed. Only those portions of the old stream which parallel and are close to the median route are used. The lengths of channel and their cut-offs and of the old channel used are given on PLATE 20. From Carlyle northward the new channel follows closely the west line of the flood plain until Keysport is reached. Then the new channel runs on nearly a median line to Vandalia, making a new length of nearly one-half of the old length. The entire new channel is made up of 25.47 miles of cut-offs and 4.82 miles of old channel. This is a total of 30.29 miles compared with 55.18 miles of the former river, a reduction of 45%. The difference in elevation between Carlyle and Vandalia is 42 feet. From this the average slope of the old channel is 0.0001441. The shortened channel increases this slope to 0.0002626, or 1.82 times the former slope.

At Carlyle the bottom of the present channel is at elevation 408. The banks of the river are at an elevation of 423. Thus it is possible to construct a channel 15 feet deep. On northward from Carlyle the ground rises enough so that this depth can be maintained. A channel with a bottom width of 100 feet is the largest that can be constructed economically. In channels wider than 100 feet the cost of construction is so increased as to make their use almost prohibitive. The proposed width of the new channel is 100 feet and the side slopes one foot on the horizontal to one foot vertical. When water is at bank

PROPOSED STRAIGHTENING
KASKASKIA RIVER
CARLYLE TO VANDALIA.

Length old channel	Length cut-off	Length old channel used.
3.59 Miles	2.38 Miles	
1.27		1.27
1.83	1.16	
0.22		0.22
11.83	5.78	
0.46		0.46
5.64	1.82	
0.33		0.33
2.02	0.92	
0.42		0.42
2.68	1.48	
0.20		0.20
6.99	3.50	
0.40		0.40
2.71	1.35	
1.25		1.25
13.07	7.08	
0.27		0.27
55.18	25.47	4.82

Total length of new channel 30.29 miles

Total fall 42 feet

Old slope 0.0001441

New slope 0.0002626

Old velocity 1.90 feet per second

Old velocity increased by

increasing r from 10.2 to 12.1 1.14 times

" s " .0001441 to .0002626 1.32 "

decreasing n " .050 to .030 1.53 "

New velocity 2.30 times old velocity

New velocity 4.37 feet per second.

full stage in the old river the new channel will have water 15 feet deep flowing thru it.

At Carlyle at bank full stage the discharge is 4270 feet per second, area of cross-section 2250 square feet, width of stream 200 feet, slope 0.0001441 n 0.050, the wetted perimeter 220 feet, and the mean hydraulic radius 10.2 feet. By dividing the discharge by the cross-section the mean velocity is found to be 1.90 feet per second. By Kutter's formula the value of c is 49.7. Then by Chezy's formula the velocity is computed to be 1.90 feet per second, which checks with the first value.

In the new channel the velocity will be increased by three factors: (1) the increase in the mean hydraulic radius due to the deeper stream; (2) the increase in slope caused by the shorter course; and (3) the reduction in the roughness coefficient, n, resulting from the straighter and cleaner stream.

The increase in the mean hydraulic radius, r, makes the following increase in the velocity. In a channel with a bottom width of 100 feet and one on one side slopes and water 15 feet deep the area of cross-section is 1725 square feet and the wetted perimeter 142.4 feet. The mean hydraulic radius is 1725 divided by 142.4, or 12.1 feet. A change in r makes a change in the velocity in two ways; directly as the square root and by increasing c. The ratio of the new r to the old is 12.1 to 10.2 or 1.19. The square root of this is 1.09, the ratio of increase in velocity. Using the original values of n and s but the new value of r to compute c, it becomes 51.9. The ratio of increase from 49.7 to 51.9 is 1.05. The total increase in velocity due to the change in r is 1.09 times 1.05 or 1.14.

The increase in slope also increases the velocity in two ways, directly as the square root and by decreasing c. The ratio of the new slope to the old is 0.0002626 to 0.0001441, or 1.82. The square root of this is 1.35, the ratio of increase in the velocity. As before using all the old factors

except that for slope the new c becomes 48.7. The ratio ofthe new c to the old one is 0.98. This is the ratio of increase in the velocity and is really a small decrease. The total change in the velocity is 1.35 times .98 or 1.32.

The reduction in the value of n increases the velocity by increasing c. Again using all the former factors except n and substituting 0.030 for 0.050 for the value of n in Kutter's formula c becomes 77.2. The ratio of increase is 77.2 to 49.7 or 1.53, the ratio of increase in the velocity.caused by the lowering of the roughness coefficient.

The total ratio of the increase in the velocity is the product of all these factors: r, 1.14; s, 1.32; n, 1.53; a product of 2.30. The old velocity of 1.90 feet per second multiplied by 2.30 becomes 4.37 for the velocity of the flow in the proposed channel. By substituting all these new factors in Kutter's formula c is computed to be 77.2. Then by Chezy's formula the velocity is computed to be 4.37 feet per second, which check with the former value.

At Vandalia at bank full stage the river carries 4630 second-feet of water in a cross-section 2270 square feet in area at a velocity of 2.04 feet per second. The stream at this point is 156 feet wide and has a wetted perimeter of 175 feet: the mean hydraulic radius is 13.0 feet. The slope just above Vandalia is 0.000156. These factors substituted in Kutter's formula give a value of 45.0 for c. Then by Chezy's formula the velocity is computed to be 2.03 feet per second, which check with the former value.

Using the same methods of computation as at Carlyle the velocity in the proposed channel at Vandalia is found to be 5.02 feet per second, or 2.48 times the former velocity. This increase is made up of the following factors: decrease in mean hydraulic radius from 13.0 to 12.1, 0.96 time; increase in slope from 0.000,156 to 0.000,347,4, 1.46 times; decrease in the value of n from 0.060 to 0.030, 1.77 times; a combined product of 2.48 times.

The lengths of the old channel used and the new cut-offs are

listed on PLATE 21.

The straightening of a channel increases the velocity by increasing the slope and under certain conditions will increase the discharge. If the rate of run-off is not increased the increased velocity will not increase the discharge but will carry away the water in less time and at a lower gage height. For example, in a uniform channel with the water flowing at less than bank full stage the depth of water flowing will be cut in half if the velocity is doubled, providing more water does not enter the stream. In this condition, and only in this condition, an increased velocity does not mean more water flowing.

But whenever the run-off is great enough to cause the stream to overflow its banks and spread out in storage over the low lands an entirely different condition exists. Then the level of the water in the stream is kept at a constant height by the run-in from the storage area, and the volume of the flow is proportional to the increase in velocity. This is the condition that exists in the Kaskaskia watershed. The actual amount of the increase of flow will now be considered, beginning first at the upper portion of the stream and going downstream.

At Vandalia in the old channel the capacity at bank full stage is 4,630 second-feet. In the proposed channel with a bottom width of 100 feet and a depth of 15 feet the capacity will be 8,660 second feet. From the rating curve on PLATE 7 the water would have to rise to a gage height of 23 feet before there would be a discharge of that amount. But at extreme flood flow the greatest discharge ever measured at Vandaliawas 7720 second-feet. This does not mean, however, that the straightening of the channel as proposed would do away with all over-flow. The water comes in very much faster than this and it is stored over the low lands. Also the channel at Vandalia is restricted by the railroad bridge. The amount of flooding that may be expected with the proposed channel will be computed from the records of discharge and of over-

flow.

The May 1908 flood was the greatest but one in the memory of the oldest inhabitants. A comparison between its over-flow at that time and what it probably would have been, had the stream benn improved as now proposed, will be of value here.

At Vandalia the river first over-flowed its banks on the 5th of May and remained out until the 21st. The channel was so restricted by the railroad bridge that the flood-flow could increase to only 7,720 second-feet. A vast volume of water goes into storage over the low-lands and the run-off is so gradual that the period of over-flow is unduly lengthened. Mr. Jacob A. Harman in his report lists the amounts of storage and the rate of increase and decrease of the storage during the flood. The capacity at bank stage of the new channel is 8,660 second-feet, and this is equivalent to 17,180 acre-feet in 24 hours (a discharge of 1 second-foot for 24 hours is 86,400 cubic feet, or 1.983 acre-feet) .

The capacity of the old channel at Vandalia at bank stage is 4,630 second-feet, while in the proposed channel the discharge is 8,660 second-feet. This increased flow is not enough to prevent all flooding for that would require a capacity of at least 35,000 second-feet. But the increased flow will lessen the time of over-flow, and lessen the frequency of the periods of shallow over-flows. It is these small floods that do the heavy damage, for they are more frequent and almost as destructive as the large floods. The time of inundation if it continues only three days is long enough to kill or seriously damage any growing crops.

On PLATE 22 it is shown that the time of over-flow of the May 1908 flood, had it been discharged thru the proposed channel, would have been reduced from May 5th to 21st--16 days to May 5th to 12th--7 days. At the height of the flood a levee broke and about one-half of the flood discharge passed thru a trestle under a railroad track and did not pass the gaging station.

Effect of Straightening on the Storage of Flood Waters

between Cowden Bridge and Vandalia

Date 1908	Discharge old channel	Storage increase in acre-feet	Equivalent discharge	Storage, old channel acre-feet	Gage height
May 3	2600	-----	2600	-------	
4	4100	5353	6810	5353	13.9
5	5670	17163	14320	22516	15.0
6	7720	55508	35880	78024	19.1
7	7370	4492	9640	82516	19.3
8	7520	19954	10080	102470	20.3
9	7070	-12425	-790	90045	19.7
10	6720	-9418	1970	80627	19.2
11	6370	-5910	3430	76717	19.0
12	6170	-6294	3000	70423	18.6
13	6170	-2115	4480	68308	18.4

Date 1908	Discharge new channel	Discharge left in storage	Storage increase in acre-feet	Total Storage	Gage height
May 3	8660	-----	-----	-----	
4	8660	-----	-----	-----	
5	8660	5660	11220	11220	13.5
6	8660	27220	54000	65220	18.3
7	12280	-2640	-5230	59990	18.0
8	11930	5670	11250	72240	18.7
9	12740	-11950	-23640	48600	17.2
10	11920	-9950	-19700	28900	15.7
11	9400	-5970	-11850	17050	14.4
12	8660	-5660	-11220	5830	13.1
13	8660	-4180	-8300	----	

- indicates a decrease

This was taken into consideration in the computations and the amounts of the reduction of storage for the days after the break in the levee were reduced one-half. From the table it is seen that the gage height of the crest of the flood is decreased from 20.3 to 18.7 feet. Bank stage occurs here at 15.0 feet, thus the depth of over-flow is reduced from 5.3 to 3.7 feet. The report by Jacob A. Harman lists the acres of lands submerged at high-water and at each foot of the receeding gage height. From this list it is found that the area under water at the crest of the flood is reduced from 22,000 acres at 20.3 foot gage-height to 18,800 acres at 18.7 foot gage height, a reduction of 3,200 acres. This apparently small decrease is due to the fact that the flood plain is low and flat and that at the edges the bluffs rise steeply. The rate of run-off in the proposed channel may be expected to be much faster. In the old channel the floods passed so slowly that the over-flow waters covered the lands for weeks after the rains had ceased. By the computations, the new channel may be expected to handle the first rush of the flood, and then when the big flow of storm water comes after the ground has been saturated, the stream will quickly rise and completely cover the flood plain. Then as soon as the rains are over the flood waters will quickly subside. The figures show that the over-flow in the old channel on the 12th of May would be as great as the greatest flooding that is apt to come at any time in the proposed channel, and on this 12th of May, the fourth day after the crest, the flood waters in the new channel are supposed to be back between the banks. This quick removal of the flood waters is of value at any time, but it is of especial value in the smaller floods.

In the Kaskaskia valley the frequency of these small floods is great, on account of the small channel and the low velocity of the stream. The capacity of the stream between its banks is less than 2 cubic feet per second per square mile of drainage area. At the crest of the May 1908 flood the rate of discharge necessary to prevent flooding was 35,880 second-feet. On the day

PROPOSED STRAIGHTENING

KASKASKIA RIVER

VANDALIA TO COWDEN BRIDGE

Length old channel	Length cut-off	Length old channel used
4.26 miles	2.73 miles	
0.51		0.51 miles
3.38	1.75	
0.43		0.43
0.98	0.29	
0.44		0.44
0.15	0.09	
0.29		0.29
0.63	0.44	
0.15		0.15
0.27	0.18	
0.23		0.23
0.24	0.14	
0.27		0.27
0.40	0.32	
0.67		0.67
0.29	0.24	
0.20		0.20
3.10	1.44	
1.10		1.10
0.76	0.63	
0.71		0.71
0.94	0.49	
1.08		1.08
6.96	4.19	
7.16		7.16
35.60	12.93	13.24

Total length of new channel	26.17 miles
Total fall	48 feet
Old slope	0.0002554
New slope	0.0003474
Old velocity	2.04 feet per second
New velocity	5.02 " " "

before 2.25 inches of rain fell and this was preceded by enough to thoroughly saturate the ground. By the Rational formula for run-off, Q = A i r, (in which Q is the total discharge in second-feet, A is the area in acres, i is the ratio of imperviousness, that is, the ratio of the inches of run-off to the inches of precipitation, and r is the rate of precipitation in inches per hour), an expression for the discharge in terms of the precipitation may be found. For the Kaskaskia River at Vandalia Q is 35,880, A is 1,267,200, and r is 2.25 divided by 24 or 0.094. i is to be found. By substitution i is found to have a value of 0.30. Now the proposed channel has a capacity of 8,660 second-feet at bank stage. Using the value of inperviousness as 0.30 and solving for r at a discharge of 8,660 second-feet, a value of 0.0228 inches per hour is found. It was assumed that this rain should fall on saturated ground, so it may be expected that the new channel would be big enough to carry the run-off from a precipitation of at least three days duration in which the average precipitation was 0.0228 inches per hour or 0.55 inches per day. By similar computations it is found that the present channel can carry between its banks an average precipitation of only 0.29 inches per day. This final conclusion is based on the assumption that the rain is of sufficient duration to saturate the ground or that the ground was saturated by previous rains of greater amounts.

In summary, the proposed channel may be expected to make the following changes at Vandalia:

Reduce distance from Cowden Bridge from 35.6 to 26.2 miles

Increase slope from 0.000,255,4 to 0.000,347,4

Increase velocity from 2.04 to 5.02 feet per second

Decrease n from 0.060 to 0.030

Increase bank capacity from 4,630 to 8,660 second-feet

Decrease time of maximum flood from 16 to 7 days

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Decrease depth of over-flow from 5.3 to 3.7 feet

Decrease acres submerged from 22,000 to 18,800

Increase average precipitation per day
of not more than 3 days duration,
the run-off from which will not
cause flooding, 0.29 to 0.55 inches

At Carlyle

The increased velocity in the new channel and the shorter distance due to the straightening of the channel both contribute to the decrease in the time of concentration. A particle of water which formerly consumed 42.6 hours in traveling 55.2 miles from Vandalia to Carlyle at a velocity of 1.90 feet per second may be expected to make the passage in the new channel over a distance of 30.3 miles at a velocity of 4.37 feet per second and consuming only 10.1 hours. Any run-off thru the new channel which lasts for more than 10 hours amy be expected to accumulate at Carlyle and increase the flood conditions there. In the old channel the run-off could last for over 40 hours before the waters accumulated at Carlyle. The proposed channel may therefore be expected at Carlyle to cause floods of greater frequency and of longer duration.

The proposed channel is carried just up to the railroad bridge at Carlyle. Below the city no improvement is made, so that no more water may pass the city than did in the original channel. The proposed channel thru Vandalia carries the water in greater volume than before, so that the result can be nothing else than an accumulation of this increased flow above the city of Carlyle. Any increase in storage will of course raise the level of the water and this will increase the discharge at the gaging station. In arriving at an estimate of the increase of storage at Carlyle the figures for the expected flow at Vandalia were used. The difference between the original flow and the estimated flow thru the new channel is asssumed to go into storage above Carlyle and to spread uniformly over the area of storage. The increase in the

depth of storage makes the same increase in the gage height at Carlyle and the new discharge was read from the rating curve and the rating curve extended. This increase in discharge was assumed to decrease the volume of storage by the full amount. Computations were made for each day, and a uniform flow during that day was assumed.

PLATE 23 lists the changes in the storage conditions at Carlyle. Before the river was out of its banks at Vandalia waters had collected in ponds on the flood plain above the city. The new channel at this stage would not flow at bank stage, but it would have a greater discharge than the original stream, for lateral drains would be provided to entirely drain the flooded area. For thisreason the flow thru the new channel is figured at bank stage. It is impossible to estimate just what the flow would be. It is certain that the amount assumed is not too small. The table shows that the greater part of the storage increase comes from the large assumed discharge before the flood flow was reached. The values are therefore not too small.

After the channel is straightened thru Vandalia the flood flow at Carlyle may be expected to be 1.5 feet higher than before. Then later during the period of run-off the floods may increase to 1.7 feet higher than before, the water is still running in faster than it runs out. This increase would cause a little increase in the duration of the flood, but this increase is not great because the increase in discharge is almost equal to the increase in flow. For all values above 25 feet the discharge at the gaging station increases directly with the gage height and at the rate of 1,520 second-feet per foot of gage. The discharge at 25-foot gage is 11,130 second-feet.

Complete drainage produces one condition that will serve to decrease the frequency and magnitude of the floods; that is, the storage of water in the surface soil. It has long been known that the water-table was lowered by complete drainage by main lines and laterals. A lower water-table makes a

Date
1908
May 3
4
5
6
7
8
9
10
11
12
13
14

Effect of Straightening on the Storage of Flood Waters

between Vandalia and Carlyle

Date	Discharge in sec-ft. At Vandalia New channel	Discharge in sec-ft. At Vandalia Old channel	Increase in acre-feet	Acres submerged between Carlyle and Vandalia	Increase in gage height	Old gage height	New gage height	Increase in discharge, sec.-ft.	Decrease in gage height	Final gage height	Original gage height	Total increase in gage height
1908												
May 3	8660	2600	12,000	10,000	1.2	21.8	23.0	1830	0.3	22.7	21.8	0.9
4	8660	4100	9,030	11,800	0.8	22.2	23.0	2580	0.4	22.6	21.3	1.3
5	8660	5670	5,830	15,400	0.4	23.1	23.5	2580	0.3	23.2	21.8	1.4
6	8660	7720	1,860	22,000	0.1	24.5	24.6	2280	0.2	24.4	23.1	1.3
7	12280	7370	9,740	29,600	0.3	26.2	26.5	2440	0.2	26.3	24.9	1.4
8	11930	7520	8,730	44,400	0.2	30.5	30.7	2430	0.1	30.6	29.1	1.5
9	12740	7070	11,230	47,600	0.2	32.3	32.5	2560	0.1	32.4	30.8	1.6
10	11920	6720	10,300	46,400	0.2	31.6	31.8	2740	0.1	31.7	30.0	1.7
11	9400	6370	6,000	44,400	0.1	30.5	30.6	2740	0.1	30.5	28.8	1.7
12	8660	6170	4,940	40,400	0.1	29.0	29.1	2740	0.1	29.0	27.3	1.7
13	8660	6170	4,940	36,800	0.1	28.0	28.1	2740	0.1	28.0	26.3	1.7
14	8660	5970	5,340	24,000	0.2	25.0	25.2	2890	0.2	25.0	23.3	1.7

dryer surface soil, and a greater volume for the absorbtion of water during the time of rainfall. This water will be held between the soil particles and will be slowly allowed to run into the streams or to be taken up by the plants. In one district in northern Indiana it was found that the maximum run-off was decreased 30% by this soil storage. Further data are not available but the fact remains that there is a distinct value in the storage of water in the surface soil.

The velocities that are expected in the proposed channel are certain to cause a great amount oferosion. At Vandalia the velocity is increased 2.48 times. The carrying capacity of flowing water increases as the fifth power of the velocity. The new flow may then be expected to carry 94 times as much silt as before. Also the size of the particles carried varies as the sixth power of the velocity, so that the size of the particles carried by the water in the proposed channel may be expected to be 232 times as great as before.

Prof. Mosier in his book on Soil Physics states on page 33 that a velocity of 24 inches per second, 2 feet per second, will roll well rounded pebbles one inch in diameter. A stream that is expected to move particles 232 times this size will certainly have a destructive action.

The soil in the flood plains of the Kaskaskia River is a loose, deep gray-silt-loam. Such a soil will not stand up against a rapid stream. The first flood thru the proposed channel will erode the banks. It will be surprising if the first big flood does not greatly widen the channel, perhaps as much as 50%. All this silt will be deposited as soon as the velocity is lowered. Some will be dropped where the waters spread out over the flooded lands, but the greater part will be carried past Carlyle and there deposited in the old channel when the velocity is decreased to the former amount. Some farmer below Carlyle will literally be given a new farm.

VII. Conclusion

The proposed plans for the improvement of the Kaskaskia River are inadequate in that they do not include the entire stream. If any one portion is to be improved that portion should be in the lower reaches of the stream. Improvement by straightening is sufficient to prevent small floods and to reduce the duration of the larger ones. However, this improvement must be carried thru the entire drainage area or those portions unimproved below the straightened part will be in greater danger from over-flow than before. The people at Carlyle who are now fighting this improvement on the grounds that it will be a damage to them are entirely right. But instead of fighting this improvement they should strive for the reclamation of the river below the city. Then it would be the duty of the people at New Athens to see that the improvement is carried to the Mississippi River in order that there shall be no hinderance to the flow thru the proposed sections.

Under the present laws it is not possible to easily organize an entire watershed into a district and to provide an organization to administer and control the entire improvement as a unit, and to maintain the improvement in a high state of efficiency after construction. At present there is no law on the statute book of the State of Illinois which will permit such an organization. Such a law must be provided before the drainage of large swamps ar areas of over-flowed lands may be taken up as a whole.